CLAIMS

1. (Original) A method of routing data through a network having a plurality of nodes interconnected by a plurality of links represented by a graph, the method comprising the steps of:

(a) receiving a path request for routing the data between a source node and a destination node in the network based on a demand;

(b) reversing the links in the graph to generate paths from the destination node to nodes along reverse paths to the source node;

(c) performing shortest-path computations for portions of the reverse paths to generate weights for potential active-path links, wherein each weight of a link in a reverse path is based on a number of reverse paths in which the link is included; and

(d) repeating the shortest-path computations of step (c) for the graph from the destination to the source using the weighted links to generate an active path satisfying the path request, wherein each link in the active path has a defined back-up path.

2. (Original) The invention of claim 1, further comprising the step of routing the data using the active path.

3. (Original) The invention of claim 2, further comprising the step of routing the data through one of the defined backup paths in response to a failure in the active path.

4. (Original) The invention of claim 1, wherein each node in the active path other than the source and destination nodes has a defined back-up path.

5. (Original) The invention as recited in claim 1, wherein step (c) includes the step of selecting each link to generate a backup path to back up for a failure of a single link.

6. (Original) The invention as recited in claim 1, wherein step (c) includes the step of selecting each link to generate a backup path to back up for a failure of a single element.

7. (Original) The invention as recited in claim 6, wherein step (c) includes the step of selecting each link to generate a backup path to back up for a failure of a each node in the active path and a failure of a last link in the active path.

8. (Original) The invention as recited in claim 7, wherein step (c) includes the step of selecting each link to generate a backup path to back up for a failure of a each node by generating a backup link for each link incident on the failed node.

9. (Original) The invention as recited in claim 1, wherein step (c) includes the step of generating usage costs for a link weight based on either complete, partial, or minimal network information.

10. (Original) The invention as recited in claim 9, wherein step (c) weights each link by generating a sum of usage costs for each back-up path link based on a number of back-up paths for which the back-up path link is employed to back-up an active path link.

11. (Original) The invention as recited in claim 9, wherein step (c) weights each link by generating a sum of usage costs for backup links based on a number of demands for which each back-up link is employed.

12. (Currently Amended) The invention as recited in claim 9, wherein, when step (c) generates the usage costs with intra-demand sharing of link capacity, step (c) further includes the step of accounting for intra-demand sharing with a vector for each node having ~~havings~~ the amount of demand for backup paths of previously routed demands, each usage cost being an incremental usage cost based on demand reserved for each backup path on a link accounted for with a corresponding element of the vector for the link.

13. (Currently Amended) The invention as recited in claim 9, wherein usage costs account for intra-demand sharing of link capacity [,] .

14. (Original) The invention as recited in claim 9, wherein step (c) generates usage costs based on complete information for failure of a single link of the plurality of links, wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with $l(u,v)$ is :

$$\theta_{ij}^{uv} = \begin{cases} 0 & if \delta_{ij}^{uv} + b \le G_{uv} \\ & and (i,j) \ne (u,v) \\ \delta_{ij}^{uv} + b - G_{uv} & if \delta_{ij}^{uv} + b > G_{uv} and \\ & R_{uv} \ge \delta_{ij}^{uv} + b - G_{uv} \\ & and (i,j) \ne (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$ and is equivalent to $(C_{ij} - F_{ij} - G_{ij})$, where C_{ij} is the total capacity of the links.

15. (Original) The invention as recited in claim 9, wherein step (c) generates usage costs based on partial information for failure of a single link of the plurality of links to route a current demand b, wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with $l(u,v)$ is :

$$\theta_{ij}^{uv} = \begin{cases} 0 & if F_{ij} + b \le G_{uv} and \\ & (i,j) \ne (u,v) \\ F_{ij} + b - G_{uv} & if F_{ij} + b > G_{uv} and\, R_{uv} \ge \\ & F_{ij} + b - G_{uv} and (i,j) \ne (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path;

F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$.

16. (Original) The invention as recited in claim 9, wherein step (c) generates usage costs based step (c) generates usage costs based on complete information for failure of either a single node of the plurality of nodes or a single link of the plurality of links to route a current demand b, wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with $l(u,v)$ is :

$$\theta_{ij}^{uv} = \begin{cases} 0 & if \sum_{(j,k)\in E} \delta_{jk}^{uv} + b \le \\ & G_{uv} and\,(i,j) \neq (u,v) \\ \sum_{(j,k)\in E} \delta_{jk}^{uv} + b - G_{uv} & if \sum_{(j,k)\in E} \delta_{ij}^{uv} + b > G_{uv} \\ & R_{uv} \ge \sum_{(j,k)\in E} \delta_{jk}^{uv} \\ & + b - G_{uv} and \\ & (i,j) \neq (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$ and is equivalent to (C_{ij} - F_{ij} - G_{ij}), where C_{ij} is the total capacity of the links..

17. (Original) The invention as recited in claim 9, wherein step (c) generates usage costs based step (c) generates usage costs based on partial information for failure of either a

single node of the plurality of nodes or a single link of the plurality of links to route a current demand b, wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with $l(u,v)$ is :

$$\theta_{ij}^{uv} = \begin{cases} 0 & if \sum_{(j,k)\in E} F_{jk} + b \leq G_{uv} \\ & and\ (i,j) \neq (u,v) \\ \sum_{(j,k)\in E} F_{jk} + b - G_{uv} & if \sum_{(j,k)\in E} F_{jk} + b > G_{uv} \\ & and\ R_{uv} \geq F_{ij} + b - G_{uv} \\ & and\ (i,j) \neq (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$..

18. (Original) The invention as recited in claim 1, wherein the method is implemented by a processor of a route server coupled to the plurality of nodes and he plurality of links, wherein the network is a packet network.

19. (Original) The invention as recited in claim 1, wherein the method is implemented by a processor of one or more of the plurality of nodes, wherein the network is a packet network.

20. (Original) Apparatus for routing data through a network having a plurality of nodes interconnected by a plurality of links represented by a graph, comprising:

a network signaling module that receives a path request for routing the data between a source node and a destination node in the network based on a demand;

a first processor module, coupled to the network signaling module, that reverses the links in the graph to generate paths from the destination node to nodes along reverse paths to the source node; and

a second processor module performing shortest-path computations for portions of the reverse paths to generate weights for potential active-path links, each weight of a link in a reverse path based on a number of reverse paths in which the link is included; and

wherein the second module repeats the shortest-path computations for the graph from the destination to the source using the weighted links to generate an active path satisfying the path request, wherein each link in the active path has a defined back-up path.

21. (Original) The invention of claim 20, further comprising a route server that routes the data using the active path.

22. (Original) The invention of claim 21, wherein a router routes the data through one of the defined backup paths in response to a failure in the active path.

23. (Original) The invention of claim 20, wherein each node in the active path other than the source and destination nodes has a defined back-up path.

24. (Original) The invention as recited in claim 20, wherein the second module selects each link of the active path to generate a backup path to back up for a failure of a single link.

25. (Original) The invention as recited in claim 20, wherein the second module selects each link of the active path to generate a backup path to back up for a failure of a single element.

26. (Original) The invention as recited in claim 25, wherein the second module selects each link in the active path to generate a backup path to back up for a failure of a each node in the active path and a failure of a last link in the active path.

27. (Original) The invention as recited in claim 26, wherein to generate a backup path to back up for a failure of each node selects a backup link for each link incident on the failed node.

28. (Original) The invention as recited in claim 20, wherein each weight of a link includes usage costs based on either complete, partial, or minimal network information.

29. (Original) The invention as recited in claim 28, wherein each link weight is a sum of usage costs for each back-up path link based on a number of back-up paths for which the back-up path link is employed to back-up an active path link.

30. (Original) The invention as recited in claim 28, wherein each link weight is a sum of usage costs for backup links based on a number of demands for which each back-up link is employed.

31. (Original) The invention as recited in claim 28, wherein usage costs account for intra-demand sharing of link capacity.

32. (Original) The invention as recited in claim 31, wherein, to account for intra-demand sharing, a vector for each node maintains the amount of demand for backup paths of previously routed demands, each usage cost being an incremental usage cost based on demand reserved for each backup path on a link accounted for with a corresponding element of the vector for the link.

33. (Original) The invention as recited in claim 28, wherein usage costs are based on complete information for failure of a single link of the plurality of links, and wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with $l(u,v)$ is :

$$\theta_{ij}^{uv} = \begin{cases} 0 & if \delta_{ij}^{uv} + b \le G_{uv} \\ & and (i,j) \ne (u,v) \\ \delta_{ij}^{uv} + b - G_{uv} & if \delta_{ij}^{uv} + b > G_{uv} and \\ & R_{uv} \ge \delta_{ij}^{uv} + b - G_{uv} \\ & and (i,j) \ne (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path;

δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$ and is equivalent to $(C_{ij} - F_{ij} - G_{ij})$, where C_{ij} is the total capacity of the links.

34. (Original) The invention as recited in claim 28, wherein usage costs are based on partial information for failure of a single link of the plurality of links to route a current demand b, and wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with $l(u,v)$ is :

$$\theta_{ij}^{uv} = \begin{cases} 0 & if F_{ij} + b \leq G_{uv} and \\ & (i,j) \neq (u,v) \\ F_{ij} + b - G_{uv} & if F_{ij} + b > G_{uv} and\, R_{uv} \geq \\ & F_{ij} + b - G_{uv} and\, (i,j) \neq (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$.

35. (Original) The invention as recited in claim 28, wherein usage costs are based on complete information for failure of either a single node of the plurality of nodes or a single link of the plurality of links to route a current demand b, and wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with link $l(u,v)$ is:

$$\theta_{ij}^{uv} = \begin{cases} 0 & if \sum_{(j,k)\in E} \delta_{jk}^{uv} + b \leq \\ & G_{uv} and\, (i,j) \neq (u,v) \\ \sum_{(j,k)\in E} \delta_{jk}^{uv} + b - G_{uv} & if \sum_{(j,k)\in E} \delta_{ij}^{uv} + b > G_{uv} \\ & R_{uv} \geq \sum_{(j,k)\in E} \delta_{jk}^{uv} \\ & + b - G_{uv} and \\ & (i,j) \neq (u,v) \\ \infty & Otherwise \end{cases}$$

where A_{ij} represents the set of demands that use link $l(i, j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i, j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i, j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i, j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i, j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$ and is equivalent to $(C_{ij} - F_{ij} - G_{ij})$, where C_{ij} is the total capacity of the links.

36. (Original) The invention as recited in claim 28, wherein usage costs are based on partial information for failure of either a single node of the plurality of nodes or a single link of the plurality of links to route a current demand b, wherein the usage cost θ_{ij}^{uv} of link $l(i,j)$ with link $l(u,v)$ is:

$$\theta_{ij}^{uv} = \begin{cases} 0 & if \sum_{(j,k)\in E} F_{jk} + b \leq G_{uv} \\ & and\,(i,j) \neq (u,v) \\ \sum_{(j,k)\in E} F_{jk} + b - G_{uv} & if \sum_{(j,k)\in E} F_{jk} + b > G_{uv} \\ & and\, R_{uv} \geq F_{ij} + b - G_{uv} \\ & and\,(i,j) \neq (u,v) \\ \infty & Otherwise \end{cases}$$

where i, j, u, and v are nodes of the plurality of nodes; A_{ij} represents the set of demands that use link $l(i,j)$ for each demand's active path and the set B_{ij} represents the set of demands that use link $l(i,j)$ for each demand's backup path; δ_{ij}^{uv} is the sum of all the demands that use link $l(i,j)$ on the active path and link $l(u, v)$ on the backup path; F_{ij} represents the total amount of bandwidth reserved for the demands in the set A_{ij} that use the link $l(i,j)$ on the active path; G_{ij} represents the total amount of bandwidth reserved for backup path demands (in the set B_{ij}) whose backup paths use link $l(i,j)$, and R_{ij} represents the residual bandwidth of link $l(i,j)$.

37. (Original) The invention as recited in claim 20, wherein the apparatus is included in a processor of a route server coupled to the plurality of nodes and he plurality of links, wherein the network is a packet network.

38. (Original) The invention as recited in claim 20, wherein the apparatus is included in one of the plurality of nodes, wherein the network is a packet network.

39. (Original) The invention as recited in claim 20, wherein the apparatus is included in a either an MPLS or an IP packet network.

40. (Original) A computer-readable medium having stored thereon a plurality of instructions, the plurality of instructions including instructions which, when executed by a processor, cause the processor to implement a method for routing data through a network having a plurality of nodes interconnected by a plurality of links represented by a graph, the method comprising the steps of:

(a) receiving a path request for routing the data between a source node and a destination node in the network based on a demand;

(b) reversing the links in the graph to generate paths from the destination node to nodes along reverse paths to the source node;

(c) performing shortest-path computations for portions of the reverse paths to generate weights for potential active-path links, wherein each weight of a link in a reverse path is based on a number of reverse paths in which the link is included; and

(d) repeating the shortest-path computations of step (c) for the graph from the destination to the source using the weighted links to generate an active path satisfying the path request, wherein each link in the active path has a defined back-up path.